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Those Ubiquitous Amphipods

Editor's note: the following is adapted from an article that originally appeared in Sea Wind *5 (4), the bulletin of Ocean Voice International. For further information about* Sea Wind, *write to Ocean Voice International, Inc., 2883 Otterson Drive, Ottawa, Ontario K1V 7B2.*

Amphipods are those little comma-shaped shrimps that hop about when you overturn beach wrack at the ocean or that sidle into crevices when you dislodge rocks at the lake-side. They go by the none too endearing name of beach flea, skeleton shrimp, well shrimp, scud or whale louse, depending on what they look like and where they are found. Not particularly palatable to humans, they are an essential food item to many fish, seabirds and whales, and are important beach cleaners and food recyclers.

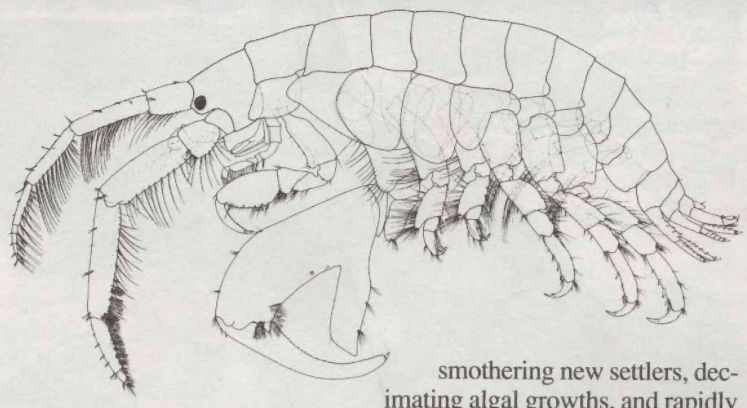
Related to true shrimps, crabs and lobsters, amphipods have probably been around for about 200 million years. They evolved in the ocean, but have since colonized fresh water, underground streams, caves and moist tropical terrestrial habitats. Although little known, they are abundant and diverse. They occur in all oceans of the world from the High Arctic to the Antarctic, from the highest beaches to the deepest ocean trenches, as well as in estuaries, glacial melt pools and most permanent bodies of freshwater.

The name amphipod comes from the greek for *amphi*, meaning 'both kinds,' and *podos*, meaning 'foot.' Amphipods are so named because of the way that their feet are directed: half forward and half rearward. The front-most legs are used for feeding, grooming, fighting, mating and signalling. The middle ones are used for walking and making webs. The hind legs are used for walking and grasping. Behind the legs are three powerful pairs of swimmerets for swimming and aerating the gills and eggs, followed by a spiny tail fan for steering and digging. Amphipods are therefore capable of adapting a variety of modes of living.

Amphipods have evolved into four major lineages: the gammarids, caprellids, hyperiids and ingolfiellids. Gammarids are the most numerous and diverse, and are the most likely of the four to be seen. Caprellids are skeleton-like and usually found crawling like miniature caterpillars on filamentous algae and hydroids under floating docks and marina ramps. Hyperiids swim in the open ocean, or attach themselves to jellyfish. Ingolfiellids are worm-like and rare, living among sand grains. So far, nearly 6000 species have been described and classified into 91 families. More species are being discovered each year.

Amphipods are not well known because they are small and tend to hide. Most are between 2 mm and 25 mm long full grown, although some species that live in the deep ocean can reach 340 mm. Some amphipods are fast movers, flitting among algae, swimming above the sea-bed chasing plankton, hopping among algal wrack cast ashore by the tides, or deftly burrowing into the shifting sands of wave-washed beaches. The more sedentary amphipods nestle under stones or among detritus, burrow into tunicates, sponges, coral and sea anemones, or build their homes out of algae, sand or detritus cemented with home-made 'amphipod silk.'

Many amphipods are suspension feeders, capturing plankton and detritus with hairy antennae, or are algae cleaners, algae eaters, sand lickers, deposit feeders, predators or scavengers. Tiny *Dulichia* and *Dyopedos* fish for passing prey from long wispy filaments of silk and sand built on hydroids and sea urchin spines. Some amphipods parasitize fish and whales; others bore into kelps and wood pilings.



Amphipods can be pests to lobster and crab fishers, attacking the bait and catches, or chewing the nets. Some attack scuba divers, leaving exposed skin sore and bloodied. But scavenging amphipods have also proven helpful to Inuit and museum preparators, who have used them to clean skins and skeletons.

Many amphipods mimic the colours of their background and have banding or spotting patterns to enhance camouflage. Some mimic snails and sea slugs to avoid being eaten by fish. Others bear long spines to deter predators. The white band on *Chromatopleustes oculatus* causes this amphipod to look like a small air bubble as it wanders over kelp, cleaning small plants and animals from the fronds. Some amphipods live on the stinging anemones and jellyfish that their fish predators avoid. *Hyperiella dilatata* captures a small mollusc called a sea butterfly and carries it about on its back for days. The sea butterfly is armed with a chemical defence against fish predators, and imparts immunity to the amphipod as well. Some algae eaters protect themselves by absorbing algal toxins and concentrating them in their body so that they are distasteful to fish. Many amphipods incorporate red pigments into their cuticle. Because red wavelengths are rapidly absorbed by water, red amphipods become invisible in deep water.

Amphipods are important elements of aquatic food webs. They rapidly convert dead material to usable organic material. They keep beaches clean of cast-up seaweed, attack organic waste dumps and clean algae of encrusting growths. They often control community make-up by preying on competitors, overgrowing, displacing and smothering new settlers, decimating algal growths, and rapidly invading new habitats.

Amphipods are the staple food of many whales, seabirds and fish. Gray whales depend on bottom dwelling amphipods for sustenance. Other baleen whales eat pelagic amphipods. The tube-dwelling *Corophium volutator*, which populates Bay of Fundy mudflats in eastern Canada, supports 50% to 75% of the world's three million sandpipers, supplying them with sufficient nourishment to complete their fall migration from the Arctic to South America. Other species of *Corophium* are essential to salmon fingerlings in North Pacific estuaries, where the salmon fatten up and acclimate to salt water before progressing oceanward.

Like other arthropods, amphipods have a tough outer skeleton that splits and is shed as the animal grows. This creates a problem for males, because they can mate only with a female that has recently moulted, as it is only at this time that her cuticle is flexible enough to let the eggs pass out to the external brood pouch. Many males spend their adult life searching for and guarding females which are preparing to moult, either by carrying their prospective mate around with them or defending them against intrusions by other males. One species of amphipod walks around in a self-made tube of sand and shell, glues female tubes to his own and defends his harem against other males. This ensures that he will always be on hand when one of his females moults and is receptive to mating.

Not all females are so docile. Females in the genus *Jassa* will treat males as competitors for their homes unless the males present an appropriate signal of their intent to mate. This signal is a thumb that develops on the front claws only near the end of the male's life (see drawing). Although thumbless males are capable of mating, they are rejected by females and lose in battles with thumbed males. Small-bodied thumbed males do not stand a chance against large-bodied thumbed males. However, a few small males have extra adornments on their thumbs that may allow them to sneak in with the females when the large males are out defending their territory.

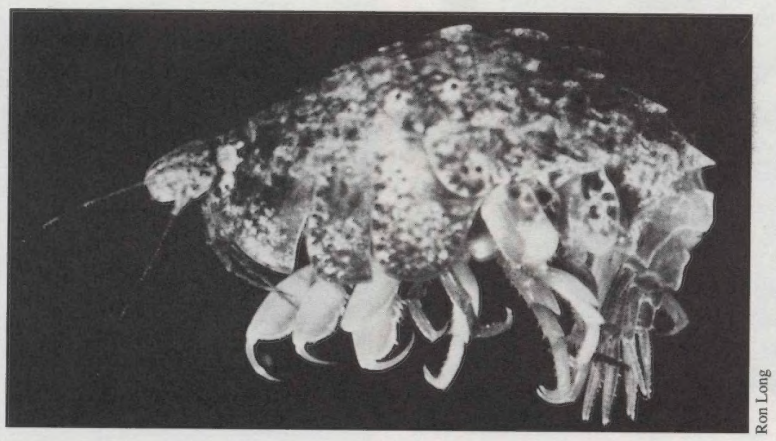
Kathleen Conlan

The more sedentary amphipods build homes cemented with home-made silk: ***Ericthonius*** *sp.*

The males of some species develop sound-producing organs for snapping or stridulating, presumably to establish their territory and to attract and guard females. Males of species that do not guard mates develop abundant chemosensors for female pheromones ('signalling perfumes') at maturity, rapidly locating and mounting receptive females before other males can establish a grip. Many scavenging and predatory amphipods are similarly well endowed with chemosensors and vibration sensors to locate prey and carcasses. This is particularly important in the deep ocean where food falls may be infrequent.

Because amphipods are abundant and widespread and reproduce rapidly, they are a useful tool for assaying the effects of acid rain and pollution caused by sewage, heavy metals, hydrocarbons, pesticides and industrial chemicals. Increasingly, scientists are finding amphipods to be sensitive indicators of environmental disturbance.

Kathleen E. Conlan
Research Division



Ron Long

Some amphipods are fast movers: ***Thorlaksonius longirostris****.*

Ron Long

Many amphipods have banding or spotting patterns to enhance camouflage: ***Orchestoides californiana****.*

Sharks on the Coral Reef

The water was roiling in over the outer edge of the reef, spilling down into the trough gouged out by eons of waves just behind the breakers. I watched the colourful damselfish delicately picking at the strands of algae, or nipping at drifting plankton. The water was too deep for me to stand, but I could rest with the tips of my flippers just touching the bottom of the coral groove, with my snorkel grazing the surface, slurping air into my lungs. It was a pleasant experience to drift in that turbulent, but well-defined tunnel of salty clear south Pacific water, taking notes on the behaviour of these delightful little creatures.

Suddenly a huge jack went streaking by. Then two more whizzed past. Instantly alert, I whirled around to see where they had come from, but there was nothing to see. My imagination? No, two enormous remoras went by. Almost by reflex, I kicked furiously, dived for the bottom and swam for the far edge of the groove: jacks and remoras are associated with sharks, so I knew that one must be approaching. I took a quick gulp of air at the surface, and looked for a convenient patch of boulder coral to hide behind. Spinning back around I hung on to the coral and held my breath. Seconds later the shark appeared. Moving effortlessly and seemingly without any real action of its tail or fins, it slid down the groove.

As I watched, I wanted to melt into the coral; the fin on the shark's back was not quite touching the surface where my snorkel had been, and its chest fins were within centimetres of the bottom. From dorsal fin tip to the tip of its pectoral fins in a vertical line, its depth — not its length — was over 2 m. As a marine biologist I was supposedly trained to be a calm observer. I am afraid I failed. I am not even sure what species it was. He passed within 2 m of where I crouched, and I didn't move until he was out of sight. When I finally struck for the surface, my lungs were screaming for air.

Later, I realized how incredibly lucky I had been — not just to survive the event, but to have been allowed to witness one of the most spectacular creatures I have ever seen. It was a magnificent beast, moving in complete confidence, one with the water, its body subtly hued in different shades of grey, white and black. And that alert eye. I will never forget that eye. He must have seen me crouching there.

Since then, I have swum with sharks on hundreds of occasions, sometimes in crowds of 40 or 50 sharks. I am never complacent in their presence, but I always marvel at the excellence of their designs, and there are many. Approximately 350 species of sharks exist in the world today. (Steve Cumbaa gives a fascinating glimpse of their evolution in *A 400 Million-Year-Old Success Story*.) Most sharks look pretty much the way you would expect them to. A few are surprisingly skinny, or fat, or bizarrely coloured, or with knobbly heads, or ridiculously large mouths. Some even have bioluminescent organs. Some never get bigger than 30 cm, while others reach a maximum length of about 20 m. In most cases, however, a shark is a shark is a shark. . . .

Very few predators will tackle a shark, other than another shark perhaps, but this is rare. Furthermore, because the shark has the relatively unusual ability to eat prey of a wide variety of sizes, including creatures as big or bigger than itself, it can feed on virtually any reasonably large animal. Thus, the shark is a 'top predator.' Of the approximately 350 species of sharks, many, but certainly not all, are found in and around coral reefs. The most common coral reef varieties fall into three main groups: requiem sharks, nurse sharks and hammerhead sharks. All three of these are potentially dangerous to humans swimmers. With a little care and common sense, however, none of them need present a danger to the diver.

Scariest looking of all the sharks are the hammerheads. These truly bizarre animals have heads that are flattened and expanded from side to side in a wide flange. On the end of each flange, a large and sensitive eye is set in a big socket. Viewed from above or below, the head really looks like a hammer. Viewed from the side, the shark looks more or less normal. The diver who comes upon this kind of shark unexpectedly will get an unpleasant surprise. Hammerheads have quite small mouths, and while they are capable of tearing prey apart, their wide-spread eyes are designed to track darting and speeding small fish, not clumsy, slow-moving objects like divers. The flange shape of the head is of special advantage in allowing the shark to make dramatically rapid turns; the flattened head acts like an aileron. To understand how this works, try holding your flattened hand out the window of a fast-moving car, and twisting it slightly to the side. Your hand will automatically snap in that direction. The same effect is created by the shark's flattened head. The shark swims swiftly through the water. If its prey fish darts to one side, a slight shift of the great flattened head pulls the huge shark in an equally quick dart to the side. Normally hammerheads are seen singly on reefs, and they can be of immense size.

A diver encountering a hammerhead will usually get only a glimpse as it glides swiftly past. Occasionally a hammerhead will threaten a diver by lowering its pectoral fins and swimming rapidly right at the diver. This is a decidedly unnerving experience! It is, however, rarely dangerous, as long as the diver stays calm and continues to look directly at the shark, ideally holding some object like a camera case in front of him. As soon as the shark swerves to the side (honest, they do swerve away!), it is time to retreat to some safe haven: back against a coral wall, around a corner or back *to the boat*. This type of shark behaviour is usually not repeated, but if it is, the boat is your only safe haven.

Avoiding 'shark accidents' usually depends on understanding their language, especially that of requiem sharks. What do you say (or not say) to a shark? Find out in our next issue.

Alan R. Emery
Director

A 400 Million-Year-Old Success Story

Sharks were swimming in every ocean of the world more than 100 million years before the first dinosaur hatched. By the time the first mammal poked its furry little head out from behind a tree fern, sharks had been the terrors of the marine world for 170 million years! They have survived every global extinction event, including the one that wiped out the trilobites and a whole group of corals at the end of the Permian (250 million years ago) and the famous event at the end of the Cretaceous (65 million years ago) which finished off the dinosaurs.

Sharks are survivors. What makes them special? Certainly one reason is that the predominantly marine environment inhabited by sharks has been more stable over time than land environments.

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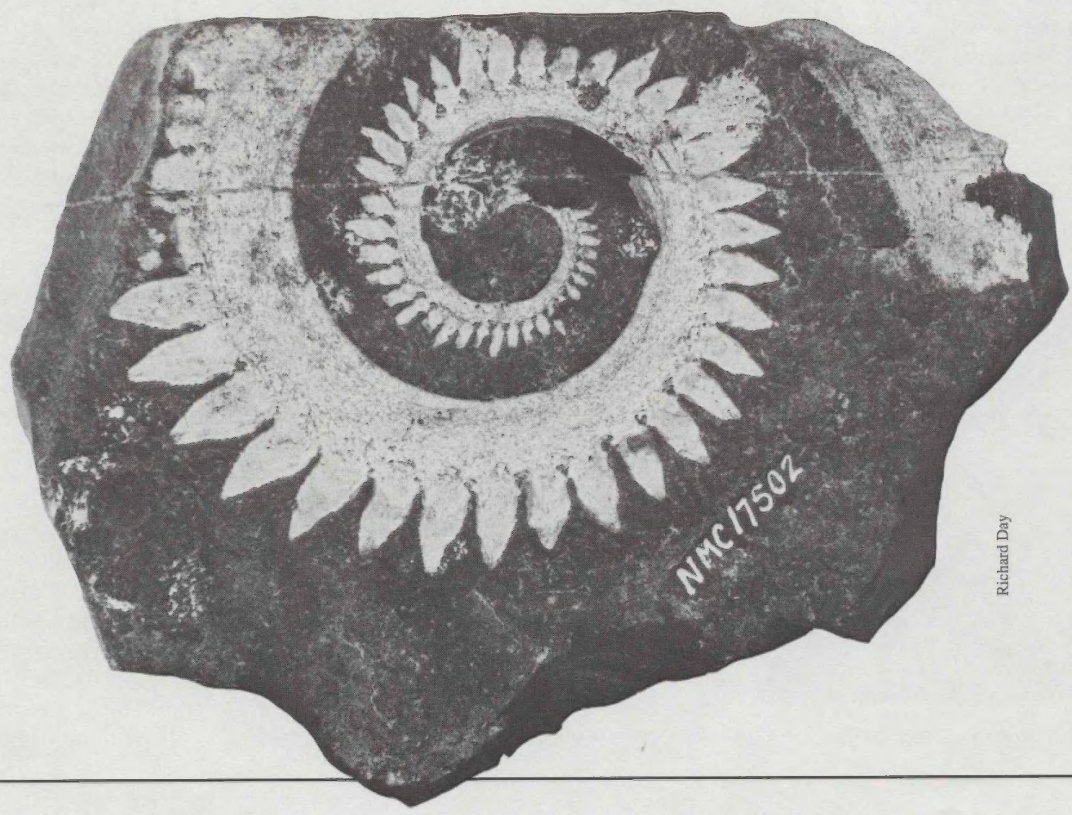

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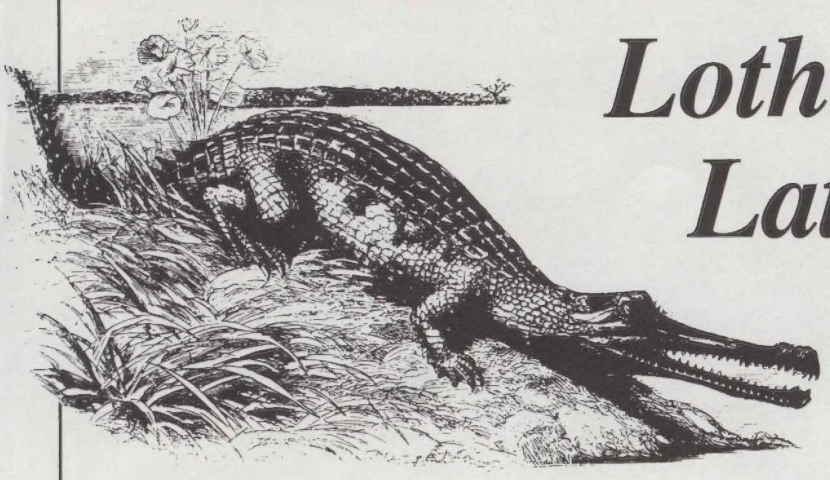


Lothagam: Window on the Late Miocene in Africa

Mention fossil discoveries in Africa and it usually conjures up images of early hominids such as Lucy or 'Zinj' from Olduvai Gorge. Often forgotten are the remains of the many other animals recovered along with the hominid finds. Study of these fossils helps us to understand how these animals have changed and diversified over the past millions of years, as well as to reconstruct the environmental and community context in which early human groups lived.

The Lake Turkana basin in northern Kenya is one of the richest fossil areas in Africa, featuring many sites with well-preserved fossil assemblages. These sites range in age from Oligocene (over 30 million years ago) to the present, indicating that the basin has been a centre of animal life for millions of years. Best known are the sites at Koobi Fora, in the eastern Lake Turkana basin, where Drs. Richard and Meave Leakey and the National Museums of Kenya (NMK) 'Hominid Gang' have recovered skulls and bones of early hominids and other animals.

One of the Turkana basin sites with an extremely well-preserved and diverse fossil assemblage is Lothagam, located a few kilometres west of modern Lake Turkana. Lothagam is a hill consisting of two parallel ridges of volcanic origin, separated from each other by a lower-lying area with about 14 km^2 of fossiliferous sedimentary deposits.

Though Lothagam Hill is situated in a desert with little rain or vegetation, the site itself is beautiful. The deposits consist largely of red, purple and orange conglomerates and sandstones, many of which have been shaped into weird forms by wind and water action. The hues of the sandstones change with the position of the sun, so the character of the site changes from hour to hour. Animal life is restricted by the availability of water, but small groups of hyenas, gazelles and serval cats can be seen. Small, mobile groups of Turkana pastoralists also live nearby.

Dating of Lothagam is not yet certain, but the earliest fossiliferous deposits are probably late Miocene, about five to seven million years old. This makes Lothagam an especially valuable site, because this period is a virtually unstudied segment of the African fossil record. Later deposits on the western peripheries of the site probably date from about four million years.

The Lothagam fossil deposits were first investigated in the late 1960s by a team of palaeontologists from Harvard University. Abundant fossils still remained at the site, and from 1990 to 1992 intensive fieldwork was conducted by the NMK team under the leadership of Dr. Meave Leakey. Over 3000 vertebrate fossils were collected by the NMK and the Harvard expeditions, primarily from the earlier deposits. These tell us that an extremely diverse terrestrial and aquatic fauna lived at Lothagam in the late Miocene, including fish, reptiles, birds and mammals, as well as fresh-water crabs and snails.

The Lothagam mammalian fauna was far more diverse than that of today, and was dominated by medium to large herbivores, including several species of elephants, hippopotami, rhinoceri, equids, pigs and many species of bovids. With this abundance of large herbivores, it is not surprising that carnivores were also numerous and diverse. Sabre-tooth cats, some as large or larger than today's lions, were common, as were several hyenas and small carnivorous mammals.

Hominids were surprisingly rare, although monkeys were common. A hominid mandible fragment was recovered by the Harvard team, and is the earliest known evidence of the hominid family in the Lothagam fossil deposits. Other than the mandible, only isolated teeth have been recovered. The large number of carnivores may have made the Lothagam area too dangerous for hominids, or perhaps hominids at this time formed only a very small percentage of vertebrates at Lothagam.

A particularly interesting and important feature of the Lothagam fauna is its transitional character. It includes some of the last members of Miocene groups in existence over 25 million years ago, as well as some of the earliest representatives of modern species. This turnover appears to have occurred in association with a change in environment. Some of the archaic mammals include *Stegotetrabelodon orbus*, a large primitive elephant with long lower and upper tusks. *Palaeotragus germaini* was an early, long-necked giraffe that lived in the Miocene, but was extinct by the Pliocene. Many of these archaic groups show adaptations to more wooded or forested environments.

Evidence of modern groups at Lothagam includes fossils of *Ceratotherium*, the earliest known representative of the white rhinoceros lineage. Early rhinos had long necks, which over time became shorter as the head became heavier. *Hexaprotodon harvadi* is a hippopotamus which was common throughout the Lothagam area. It was smaller and more agile than today's hippos, and not as water-dependent. Unlike the archaic groups, many of these more modern herbivorous animals showed progressive dental adaptations to more open, grassy environments, and presumably drier climates.

The presence of animals such as elephants and hippos, which require frequent access to water and large amounts of vegetation for feeding, shows that unlike today Lothagam was once well-watered and well-vegetated. Numerous fish, turtle, and crocodile bones also indicate that a large aquatic fauna existed, and that there was a large river nearby. Fossils of several species of turtle were recovered, as well as at least five species of crocodile.

The diversity in crocodiles is reflected in the size and shape of their snouts. Three of the Lothagam crocodile species had short to medium snouts, and probably lived and fed both on land and in inshore waters. Two other species with highly elongated snouts and slender sharp teeth (somewhat resembling modern gavials — see drawing) were probably fish eaters, spending most of their time in open waters. This very unusual diversity of crocodiles — there is only one species in eastern African waters today — and their large size — some individuals are estimated to have been over 14 m in length — would have required an abundant aquatic fauna to support it.

The fish fossils show there were certainly plenty of fish for the crocodiles to eat. A total of 14 fish families are represented in the Lothagam deposits (there are 16 in modern Lake Turkana), making this the most complete fossil fish assemblage we have from the period prior to four million years ago in Africa. The fish fossils were collected in two ways — by extensive surface survey, which allowed surface recovery of larger bones, and by micro-screening of sediments, using a wooden frame fitted with a 1 mm wire mesh screen. This made it possible to recover more than 2000 elements, mainly of fish, but also of rodents and other microfauna.

The character of the fish fauna changes considerably throughout the Lothagam sequence. The fish from early deposits are more archaic, including groups such as lungfish, tigerfish and mormyroids, fish which sense their surroundings by using electric currents. The fossil record from later deposits is dominated by cyprinids — minnow-like fishes, catfish and perch-like fishes.

One of the most interesting recoveries are teeth of an extinct fish, *Sindacharax*, a fish which apparently could grow to over 1 m in length. *Sindacharax* teeth are unusual in having numerous cusps, as do mammal teeth. They preserve well, and their presence at fossil sites tells us that *Sindacharax* were found in eastern and northern Africa between at least 25 million years and 700,000 years ago.

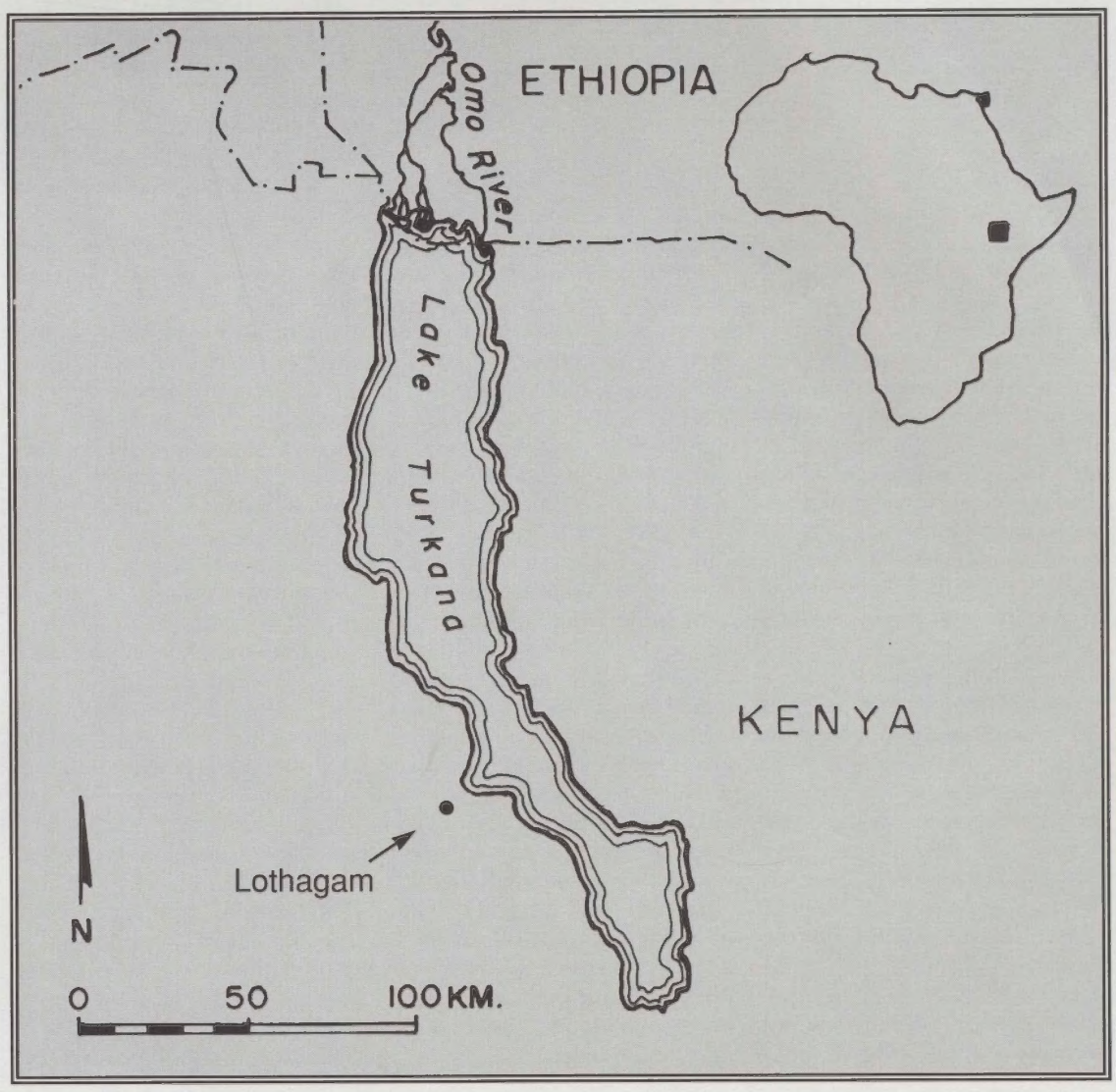
Sindacharax is one of a group of fish called characoids, now found almost exclusively in Africa and South America. This distribution suggests that characoids derived from a common group when Africa and South America were united as the super-continent Gondwanaland. While fossil characoids are so far poorly known, further studies of fossils from this group in both continents could tell us more about the common fauna in Gondwanaland, water systems on that continent, and how the fossil groups have diverged since the two land masses separated.

K. Stewart

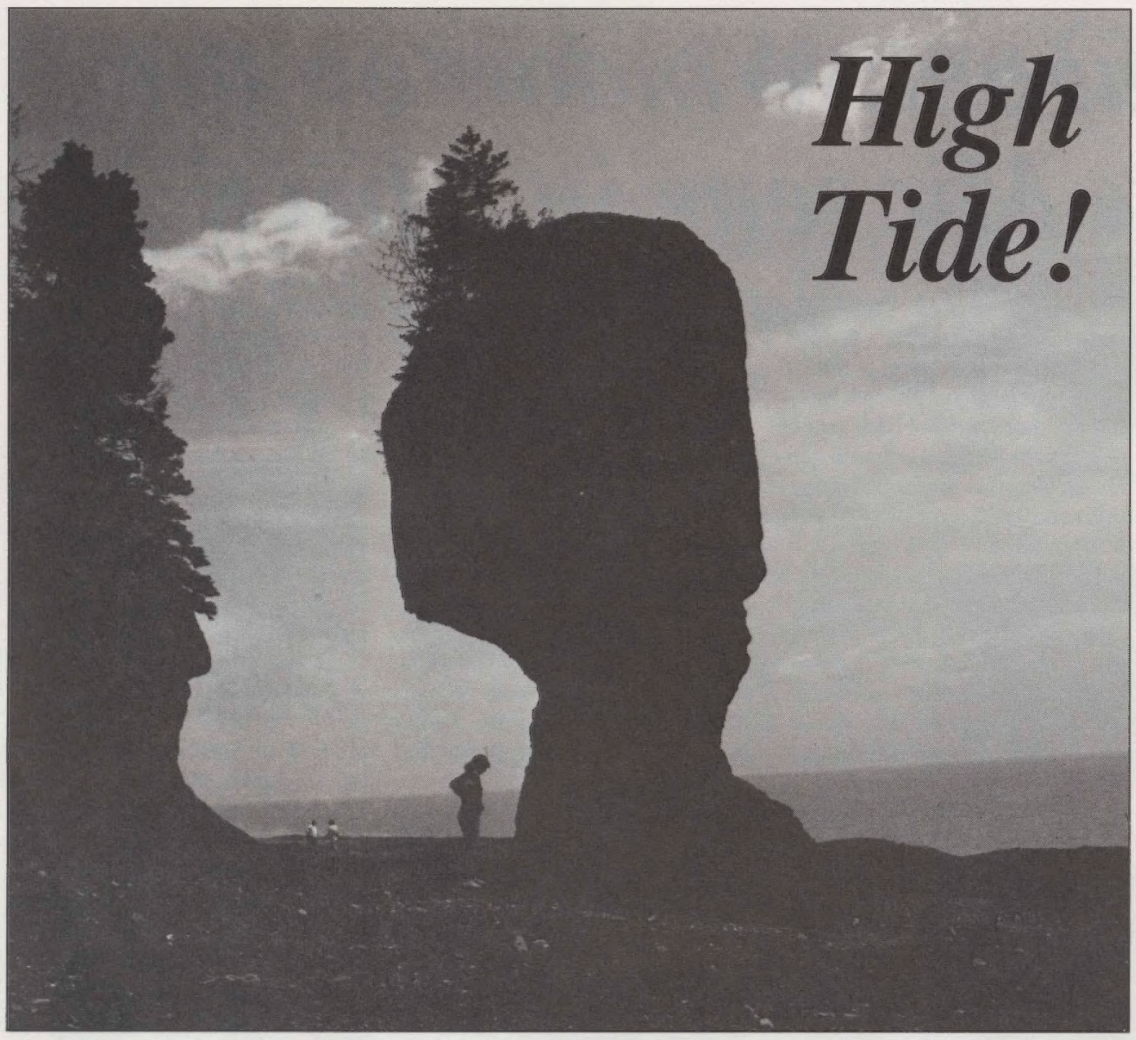
Two of the NMK team screen for micro-fossils at Lothagam.

Fieldwork is still under way, but already the fossils have told us a great deal about the animals and environment in eastern Africa five to seven million years ago. This was a critical period in animal and human evolution, when archaic groups were being replaced by modern ones. Future work at Lothagam and related sites will help to complete the picture.

Kathlyn Stewart
Research Division



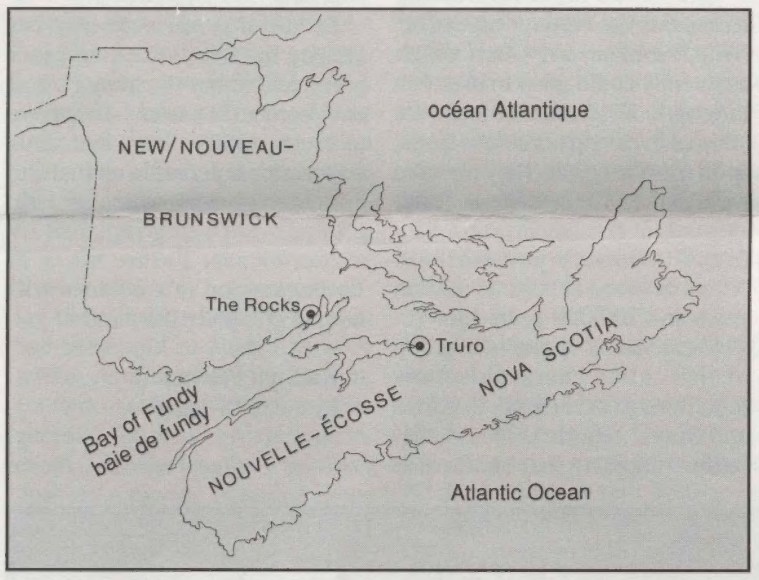
High Tide!



D.M. Jarzen

'Flowerpot' structures at The Rocks Provincial Park, New Brunswick. Note person for scale.

From the Atlantic to the Pacific to the Arctic Oceans, Canada abounds with natural wonders. Among these can be counted the rainforests of British Columbia, the majestic Rocky Mountains, the short and long grass prairies, the beautiful post-glacial lakes of Manitoba and northern Ontario, the extensive conifer forests of Quebec and the rocky coastline of the Maritime Provinces. Least known perhaps, but of importance to our economy and marine biota, are the tidal systems which affect all Canadian coastlines, especially the shores and inlets around the Bay of Fundy. Tides there are the largest recorded in the world, often reaching more than 16 m in some places.



Technically speaking, tides are ocean waves that occur every 12 hours and 25 minutes and have a wavelength of half the circumference of the Earth (approximately 20,300 km). But what causes tides, and why do we normally observe two tides a day? To better understand tides, it is necessary to recall a bit of high school physics. Simply put, tides are caused by the gravitational pull of the moon and, to a lesser extent of the sun, on the surface of the Earth.

All objects in our universe exert a pull towards each other. Smaller objects are pulled towards larger ones. Thus, when we drop a small object (say, a ball) it falls towards the ground (or more specifically, the Earth). The pull of the moon on the Earth affects the water more than it affects the planet itself. The moon's gravitational force 'pulls' the ocean water facing the moon more than the water on the other side of the Earth, causing a 'bulge' in the ocean. The water literally moves towards the moon. This is what we call the *lunar tides*.

Although the sun also pulls the Earth's water towards it, the sun's greater distance lessens the magnitude of *solar tides*. In themselves, solar tides are not significant. However, when the sun and moon are aligned at the times of the new and full moon, the combined gravitational pull of these two bodies produces the highest tides, called *spring tides*, which can occur at times other than spring. When the sun and moon are at right angles to each other (when the moon is in its first and third quarters) the gravitational pulls of the two bodies work against each other, causing lower tides, or *neap tides*.

If the moon were at rest, that is, if it were to stop orbiting the Earth, tides would occur every 12 hours because the Earth makes one rotation every 24 hours (each side affected every 12 hours). However, since the moon also orbits the Earth once every 29.5 days, the average interval between tides is about 12 hours and 25 minutes. This explains why tides do not occur exactly at the same time each day, but rather occur about 50 minutes later each day. Most coastal areas will have two high tides (*flood tides*) and two low tides (*ebb tides*) every day. These are known as *semidiurnal tides*.

As noted earlier, the world's largest tides occur in the Bay of Fundy between New Brunswick and Nova Scotia. Twice daily the ocean waters rush into the bay, creating 14 m to 16 m tides. More water moves in and out of the bay daily than all the fresh water flowing in all the Earth's rivers and streams each day! As the incoming water surges into the ever-narrowing bay, the height of the tide increases. The elongated shape and narrowing width of the bay and the ever-increasing shallowing of the bottom of the bay are factors that produce these mammoth tides. Near Hopewell Cape, New Brunswick, at The Rocks Provincial Park, the tides rise to 14 m, covering nearly a third of the now much-eroded 'flowerpot' rock pillars. The bay narrows even more at its easternmost terminus at Truro, Nova Scotia. The tide then enters the Truro River inland, reversing the seaward flow of water and creating a *tidal bore*. Twice daily the bore rushes upstream producing a spectacular, if not awe-inspiring, experience.

Anyone living in coastal areas, especially along the Bay of Fundy, is clearly aware of the daily struggle and the adaptability required of humans and ocean biota to survive in these areas. Tidal currents move marine animals back and forth, changing their habitats twice daily. Fishermen have to know the tides; they have learned when and where certain fish can best be caught. Ship lines and ferry services must also adjust their schedules in accord with tidal movements.

David M. Jarzen
Research Division

(continued from page 2)

A 400 MILLION-YEAR-OLD SUCCESS STORY

Nevertheless, other marine creatures, including shark competitors like the ichthyosaurs, mosasaurs and plesiosaurs — all marine reptiles — and large marine mammals like the whales, have not fared as well. In evolutionary terms, sharks have simply done a better job of adapting and diversifying to take advantage of environmental change and of changes in their food supply.

One possible advantage is that 'advanced' sharks, like the tiger and great white, have among the highest known brain weight to body weight ratios of all 'lower' vertebrates, exceeding even that of some birds and mammals. This, plus a similarity in brain organization to some of these 'higher' vertebrates that indicates an increased capacity for complex behaviour, which is one measure of intelligence, isn't a guarantee of survival, but it helps!

Sharks, skates and rays are related and form one major group of 'cartilaginous' fishes. These fishes have no true skeletal bone like pike or goldfish, but instead have a flexible skeleton made of cartilage, parts of which, like the vertebrae, sometimes harden or 'calcify.' Most primitive cartilaginous fish groups became extinct by about 200 million years ago, but by that time the ancestors of modern sharks and rays were well established, and by the early Cretaceous (145 million years ago), sharks looked much like they do today.

We know how many early sharks looked from a combination of painstaking research and geological luck. One of the best known fossils is that of the genus *Cladoselache*, found remarkably preserved in black shales along the south shore of Lake Erie. Although found in rocks more than 360 million years old, the body outline of these sharks is frequently preserved; even such soft parts of the anatomy as muscle fibres and kidneys may be fossilized.

Modern and recent fossil sharks differ from primitive Palaeozoic forms in many ways. The fins have become more flexible, fin spines have become smaller or have disappeared, the vertebral column has become calcified, and the upper jaw has become movable relative to the braincase. These changes mean that sharks have become more manoeuvrable fish, able to 'munch' with much greater flexibility.

Throughout their evolution, sharks have maintained their dominant role as marine predators. They have diversified into two general forms: the streamlined, elongated, fast and aggressive sharks with piercing and slashing teeth, and the flattened, 'winged,' whip-tailed skates and rays with an array of crushing teeth. This latter group is adapted to a bottom environment.

In Canada, fossil teeth, spines and occasionally vertebrae of extinct sharks are known from some of the Arctic islands, Nova Scotia, British Columbia, Alberta, Saskatchewan and Manitoba, and can be presumed to exist in most places where sedimentary rocks were deposited in a marine environment within the last 350-400 million years.

The fossils most often found are teeth, partly because they are made of an enamel-like material and fossilize well, but also because sharks produce teeth in such huge numbers. The teeth of sharks are not anchored in bone, but in skin-like tissue, and are produced continuously throughout the life of the shark. The 'working' teeth of sharks are visible when the mouth is open, but sharks have several extra rows of teeth on the inside of their upper and lower jaws. When the front teeth are lost or fall out during fighting or feeding, the next in line on the inside of the jaw rotate forward into position. Fossil evidence indicates that ancient sharks followed this same pattern.

The photograph shows a tooth whorl of a fossil shark of the genus *Helicoprion*. This early 'experiment' in shark tooth design had a flat spiral with the smallest teeth on the inner curves and the largest, active teeth on the outside. This spiral of teeth would have fit, somewhat like a circular saw blade, at the front where the two jaws come together. The teeth on each side of this 'saw blade' would have been flat, crushing teeth, somewhat like those of modern skates and rays. This unusual fossil from our collections was found on Ellesmere Island in Canada's High Arctic by Dr. Walter Nassichuk of the Geological Survey of Canada, in rocks about 265 million years old. Similar tooth whorls have been found in other parts of North America, Australia and Antarctica.

It has been estimated that a single tiger shark may produce 24,000 teeth over a ten-year period. With thousands of individuals of hundreds of species swimming in the waters of the world for each of the last 400 million years, it's not surprising that shark teeth are among the most common vertebrate fossils!

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